JC07 Rec'd PCT/PTO 07 DEC 2001

FORM-PTO-1390 (Rev. 9-2001) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
025219-360

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)
Unassigned 10/009335

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FR00/01804	June 28, 2000	July 1, 1999

TITLE OF INVENTION
SYSTEM OF ARTIFICIAL INTELLIGENCE FOR THE CLASSIFICATION OF EVENTS, SUBJECTS OR SITUATIONS FROM SIGNALS AND DISCRIMINANT PARAMETERS PRODUCED BY MODELS

APPLICANT(S) FOR DO/EO/US
Jean-Denis MULLER; Stephanie MULLER CARCELES

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
    PCT Request, PCT Publication, International Search Report, Chapter II Demand, International Preliminary Examination Report

21839

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U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
Unassigned 10/009335	PCT/FR00/01804	025219-360

	CALCULATIONS	PTO USE ONLY
21. ☒ The following fees are submitted:		
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .... $1,040.00 (960) International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... $890.00 (970) International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $740.00 (958) International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) .... $710.00 (956) International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00 (962)		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890.00	
Surcharge of **$130.00 (154)** for furnishing the oath or declaration later than 20 ☐ 30 ☐ months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	7 -20 =	0	X$18.00 (966)	$ 0	
Independent Claims	1 -3 =	0	X$84.00 (964)	$ 0	
Multiple dependent claim(s) (if applicable)			+ $280.00 (968)	$	

TOTAL OF ABOVE CALCULATIONS =	$ 890.00	
Reduction for 1/2 for filing by small entity, if applicable (see below). +	$	-
SUBTOTAL =	$ 890.00	
Processing fee of **$130.00 (156)** for furnishing the English translation later than 20 ☐ 30 ☐ months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$ 890.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00 (581)** per property +	$ 40.00	
TOTAL FEES ENCLOSED =	$ 930.00	
	Amount to be refunded:	$
	charged:	$

a. ☐ Small entity status is hereby claimed.

b. ☒ A check in the amount of $ 930.00 to cover the above fees is enclosed.

c. ☐ Please charge my Deposit Account No. 02-4800 in the amount of $______ to cover the above fees. A duplicate copy of this sheet is enclosed.

d. ☐ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-4800. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

BURNS, DOANE, SWECKER & MATHIS, L.L.P.
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25,885
REGISTRATION NUMBER

DECEMBER 6, 2001
DATE

JC07 Rec'd PCT/PTO 07 DEC 2001
10/009335

Patent
Attorney's Docket No. 025219-360

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of Muller, et al.	)	Group Art Unit: Unassigned
Application No.: Unassigned	)	Examiner: Unassigned
Filed: Herewith	)	
For: SYSTEM OF ARTIFICIAL INTELLIGENCE FOR THE CLASSIFICATION OF EVENTS, SUBJECTS OR SITUATIONS FROM SIGNALS AND DISCRIMINANT PARAMETERS PRODUCED BY MODELS	)	

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to examination, please amend the subject application as follows:

IN THE SPECIFICATION

Please amend the specification by inserting before the first line the sentence: "This application is a national phase of PCT/FR00/01804 which was filed on June 28, 2000, and was not published in English."

REMARKS

Entry of the foregoing amendment to the Specification is requested to comply with the requirements of 37 C.F.R. 1.78(a)(2).

If the Examiner should be of the opinion that a telephone conference would be helpful in resolving any outstanding issues, the Examiner is urged to contact the undersigned.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: ____________________
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Date: December 6, 2001

SYSTEM OF ARTIFICIAL INTELLIGENCE FOR THE CLASSIFICATION OF EVENTS, SUBJECTS OR SITUATIONS FROM SIGNALS AND DISCRIMINANT PARAMETERS PRODUCED BY MODELS

Technical field

The present invention relates to a system of artificial intelligence for the classification of events, objects or situations from signals and discriminant parameters produced by models.

In particular, the invention applies to the classification of seismic events. Such a classification will be considered as a non-limiting example in the following description.

State of Prior Art

Automatic classification of seismic events

Automatic classification of seismic events is a relatively recent problem, since the problem was only really approached in the 1980's. These works were generally oriented towards the search for discriminant parameters (that is say making classification possible) in seismic signals. Many potential characteristics were proposed with a view to future automatic classification. After 1990, attempts to carry out automatic classification began to appear in published articles, either using neural techniques or rule-based systems. These works sought to separate earthquakes of natural origin from explosions. None of these articles processes the discrimination of rock failure in the mining industry ("rock bursts").

Because of the complexity of the problem, these articles clearly demonstrate the need for perfecting automatic systems capable of learning. Neural methods are therefore often proposed to carry out automatic discrimination of seismic events, but with limitations analysed below. The models suggested most often are multilayer perceptrons with complete connections between successive layers.

All these articles seek to determine the origin of the earthquake starting from characteristics extracted solely from the signals. The highest level data (date, time, latitude, longitude, magnitude etc.) are never used for classification. But seismologists know the difficulty of discriminating seismic signals through low level processing alone.

Works by Baumgardt and his colleagues described in document reference [1] are without doubt those which have contributed to making the greatest advances in the search for discriminant parameters.

The variations of the cepstrum, the cepstrum of a signal x being the inverse Fourier transform of the logarithm of the Fourier transform of x, are often used. It can thus be shown that the cepstrum makes it possible to visualise the phenomenon of micro-delays present in the blast signals characterised by a greater variance. The document reference [2] also notes this property, nonetheless pointing out that the absence of this characteristic does not permit any deduction concerning the class of the event.

The ratios of the amplitudes of the different types of waves can also serve as discriminants. The

document reference [3] studies a whole series of amplitude ratios (P_n/L_g, P_g/L_g, L_g/R_g). These ratios are described as being able to provide good discrimination.

The same authors also introduce ratios of spectral densities of power of the different types of waves detected. Just like the amplitude ratios, these discriminants are used by all the studies seeking discriminants in seismic signals. In order to characterise the explosions, ratios have also been used for power spectral densities of one wave type, S here, for bands of different frequencies, that is to say the ratio of the power spectral density of S in the range 1-2 Hz to the power spectral density of this same phase in the 7-20 Hz band. The ratio between the power spectral densities of the S wave below and above 10 Hz is also given as a good separator between explosions and earthquakes.

The document reference [4] notes that the propagation time of signals from a mine has a constant time $t_{Sg}-t_{Pg}$ for a given recording station. This propagation time is presented as a potential characteristic for a mine, nevertheless remaining less reliable than the preceding characteristics.

The document reference [5] suggests using the presence of the surface wave from earthquakes to discriminate them from nuclear explosions at regional distances. Characterisation of the presence of a surface wave is made indirectly by comparing the magnitudes m_b and M_s. For two seismic events of the same magnitude m_b, the magnitude of the surface wave M_s is generally higher in the case of an earthquake because

of the presence of the surface wave than in the case of an explosion. In fact, this crustal Rayleigh wave enters into the calculation of the magnitude M_s and its presence is subordinate to the phenomenon of shearing, absent in the case of nuclear explosions. Representation of the difference (m_b-M_s) as a function of m_b makes it possible to verify this hypothesis. Nevertheless, the calculation of the magnitude M_s depends on the periodicity of the signal recorded and it is not possible to be rigorous for regional events. On the contrary, the presence of a surface wave corresponding to a sedimentary Rayleigh wave in close seismic signals, characterises events of an artificial nature. A detection method for this second type of surface wave consists of searching for its presence directly in the spectrogram of the signal, its frequency being known (between 0.5 and 1.5 Hz) and its supposed time of arrival can be calculated from its average speed of propagation and the distance separating the epicentre from the recording station.

The systems described in documents of prior art are not operationally credible for several reasons:

- studies carried out by geophysicists, usually rich and detailed concerning proposals for discriminant parameters, do not suggest any reliable method for automatic exploitation of these parameters.
- studies carried out by computer specialists propose systems that do not take sufficient account of the complementarity of data and geophysical knowledge.

Most of prior art studies use data bases of seismic events of extremely reduced size, with the

consequence that they do not permit correct statistical learning. Classification is usually carried out on bases with fewer than one hundred events, as described in the documents reference [2] and [6]. One of the biggest bases found in prior art documents comprises only 312 events, as described in document [4]. The direct consequence is that the margins of error for the results presented are very high, which cannot provide great confidence in these results.

The geographic spread of the examples in the data base is a very important element. Most bases group together events which have taken place in regions of restricted size (several tens of kilometres per side), where the geological properties under ground have little diversity. The search for general discriminants is therefore biased, the discriminants only being effective for a given region.

Moreover, as described in the document reference [1], the events of the two classes to be discriminated can come from two clearly distinct geographic regions, sometimes as far apart as several hundreds of kilometres. It is therefore impossible to know to what extent the "colouring" of the signals by the geological layers travelled through influences the discrimination, rather than the signals themselves. But seismologists know that this "colouring" is far from negligible and that localisation information is very important.

Generally, a very limited number of recording stations is used. The signals are recorded by two or three stations at maximum, but usually by only one single station. The seismic event is thus represented

by a single signal, which reduces usable information considerably.

Finally, the events integrated into the data base are very generally selected according to previously defined criteria: magnitude greater than a certain threshold, signal/noise ratio greater than a certain threshold, as described in document reference [2]. But this selection evidently biases the results completely.

Although prior art studies have made it possible to register a wide range of potentially useful discriminants for classification, it has proved to be very difficult to find efficient global discriminants because of the high number of distinct types of blasting and earthquakes.

In most cases, the classifiers proposed turn out to be inefficient because they are too simple (linear separators) or impossible to regulate because of their complexity. They demand enormous work on pre-processing the data, which means that the systems proposed cannot be generalised.

Example of seismic surveillance

The detection and geophysical laboratory (LDG) of the CEA has continuously surveyed the seismic activity of the earth since 1962. When a seismic event occurs in any spot on the globe, it is recorded in France by a network of forty-two vertical seismometers located on mainland territory, as shown in Figure 1, the SP stations being short-period stations and the LP stations being long-period stations. A detailed description of the network of seismometers and the

propagation of seismic waves in France is given in the document reference [7].

This network, which since its creation, used transmission by Hertzian channels, has recently moved to digital transmission by satellite. Filtering and a gain adapted to the signal make it possible to detect close earthquakes or on the other hand longer period distant earthquakes called teleseisms. The regulation of filtering parameters and gain must make it possible to find a compromise between the detection of seismic events of relatively low magnitude and background noise.

Figure 2 shows signals recorded by seismometers of the LDG laboratory located between 84 and 146 kilometres (that is SBF: 84 km; PGF: 110 km; FRF: 127 km; LMR: 136 km and LRG: 148 km) from the estimated epicentre of an earthquake of magnitude 1.9 located 10 kilometres south of Imperia in Italy on May 9, 1996 (time: 1hr 0min 59sec; latitude: 43.34; longitude: 8.19; magnitude: 1.9).

Different seismic phases are indexed on each signal, which will be used for the detailed analysis of the event.

Each year, about 9,000 close seismic events are thus detected, of which 800 to 1,200 are natural earthquakes.

The seismologists of the LDG laboratory process and analyse daily the data recorded by the stations of the French network. They publish a weekly bulletin containing the whole of the natural earthquakes in France or in the bordering regions. A similar bulletin

is published for teleseisms. Table I, given at the end of the description, is an extract from the bulletin for the period from September 9 to 15, 1998. In this table, there are the following abbreviations:

TIME OR. : time of origin (TU);
LAT : latitude of the epicentre (deg.);
LON : longitude of the epicentre (deg.);
DEP : depth of the epicentre (km);
LM : local magnitude;
MSE : mean square error (s).

This table thus comprises the ensemble of close earthquakes detected during this week and the characteristics of each event: date and time of origin, position and depth of the epicentre, magnitude, mean square error for the localisation and deduced localisation region.

Because of the great imbalance between the number of artificial events and that of natural events (in France, seismic events of artificial origin are ten times more frequent than natural seismic events), only events presumed to be earthquakes or events of non-determined class are extracted from the background noise by seismologists in order to be analysed more precisely later by a localisation software. The other signals (mainly artificial events) are archived for six months.

The procedure for analysing the signals comprises an already automated localisation, followed by a characterisation phase (determination of the event at the origin of the signals).

The analysis of the signals is carried out using a global system illustrated in Figure 3.

The aim of the invention is to compensate for the inconveniences of prior art systems by proposing a new system of artificial intelligence for classifying events, objects or situations from signals and discriminant parameters produced by models.

Description of the invention

The present invention relates to a system of artificial intelligence for the classification of events, objects or situations from signals and discriminant parameters produced by models, characterised in that it comprises at least one processing branch comprising a fuzzy expert system (FES expert) taking a decision according to high level properties and lower level discriminant parameters extracted from signals by signal processing type procedures, and capable of explaining its decision to the user through the intermediary of rules selected by order of applicability.

In this fuzzy expert system a gradient decrease is carried out on the parameters:

- $x = y/\sigma$
- $s = \ln/2\sigma^2)$
- $r = \ln(\rho)$
- d

with:

- y: position of fuzzy sets of premises
- σ: width of fuzzy sets of premises
- ρ: weight of rules

• d: degree of activation of each class for each rule.

Advantageously the system according to the invention is a multi-expert system constituted of at least two independent processing branches, organising themselves automatically through statistical learning on the data bases, having particular properties, and merged by a high level decisional system. Advantageously one branch comprises a neuro-fuzzy classifier (NFC expert) taking its decisions from high level properties and lower level discriminant parameters extracted from signals by signal processing type procedures. Advantageously another branch comprises a neural network with local connections and shared weights (TDNN) constituted of banks of non-linear adaptable filters, itself extracting discriminant information for time-frequency representation of the signals corresponding to the event.

The invention can be used in different fields of application and particularly in:

• *Surveillance of geophysical events*

The system then applies to the analysis of any geophysical event observable through signals received by the stations:

- seismic signals;
- infrasound;
- hydro-acoustic waves.

These events can be close events (called regional) or distant events (for example, teleseisms).

The function to be ensured may be:

- filtering to eliminate the non-relevant events for later processing;
- detection of special events;
- exhaustive classification into a set of groups of events of the same nature.

• *Industrial surveillance and monitoring*

The system also applies to the analysis of objects or industrial processes, as long as one has available signals or images collected by sensors. A few examples are given below:

• Quality control of manufactured objects or products: the aim is to verify the shape and/or position of objects, to detect and characterise defects. The NFC and FES detectors use measurements produced by image processing. The TDNN expert uses one or several images of the part.

• Predictive maintenance of equipment: the aim is to foresee a future failure of machines, computers, electronic equipment, sensors in order to give a warning and make it possible to implement a correction procedure before breakdown. The NFC and FES experts use measurements of high level coefficients, and correlations. The TDNN expert uses signals.

• Complex process surveillance: the aim is to verify that a production chain is operating correctly. NFC and FES experts use measurements of high level coefficients. The TDNN expert uses measurements of low level coefficients.

In the geophysical domain, the high level properties can be the location, the magnitude, the time and the date. The system according to the invention

makes it possible to carry out automatic classification of seismic events into three sets:

- natural earthquakes;
- explosions (blasting in mines and military trials);
- rock bursts (collapse of layers in mines).

The system then integrates into a chain of automatic processing to operate a filtering function of seismic events. Its principal characteristics are:

- maximum reliability: the system is able to take decisions even with corrupted or imprecise data, or even in the absence of certain information;
- access to the explanation of decisions in order to avoid any eventual doubt about a decision.

<u>Brief description of the drawings</u>

Figure 1 shows the network of seismometers belonging to the laboratory for detection and geophysics (LDG) of the centre for atomic energy (CEA) in 1998.

Figure 2 shows examples of seismic signals recorded by the network of figure 1.

Figure 3 shows a prior art global system for exploitation of geophysical systems.

Figure 4 shows the diagram of the principle of the multi-expert system for discrimination of seismic events according to the invention.

Figure 5 shows the general learning diagram of the system according to the invention, from examples.

Figure 6 shows an artificial neuron.

Figure 7 shows a network of artificial neurons.

Figure 8 shows a neuro-fuzzy classifier.

Figure 9 shows a mechanism for activation of coding cells.

Figure 10 shows examples of activation of coding cells.

Figure 11 shows a fuzzy expert system for the discrimination of seismic events.

Figures 12A to 12D show successive pre-processing applied to a seismic signal.

Figure 13 is an architecture of a network of neurons with local connections and shared weights.

Figure 14 shows the spread of epicentres of seismic events between 1962 and 1996.

Detailed description of embodiments

General description of the system

The system according to the invention comprises at least one processing branch containing a fuzzy expert system. When it comprises several branches of independent processing, one refers to a multi-expert system.

- *Multi-expert decision making*

The principle of multi-expert decision-making, which is thus one of the embodiments of the invention, is the exploitation of the synergy between several complementary processing branches. This complementarity resides in:

A. The general performances: one branch is rather generalised (fairly good performances in most cases), another is rather specialised (very good performance for certain difficult cases, a

higher level of errors in cases outside its competence).

B. The performances according to the case treated: one branch can be more able than another for treating a particular case.

C. The nature of inputs (high level signals or data).

D. The nature of outputs (single data for the class, estimation of the certitude of the decision, formal explanation of the decision).

Figure 4 shows the diagram of the principle of the multi-expert system for discrimination of seismic events according to the invention. This system is constituted of several independent processing branches, each with special properties, merged by a high level decisional system.

These branches are:

- a neuro-fuzzy classifier, NFC, making its decisions from high level properties of events (for example for seismic events: localisation, magnitude, time, day of the week) and lower level parameters extracted from the signals by procedures of the signal processing type;

- a fuzzy expert system, FES, taking a decision in an independent way from the same information, and able to explain its decision to the user through the intermediary of rules selected by order of applicability to the event being processed;

- a neural network with local connections and shared weights, TDNN, constituted of banks of non-linear adaptable filters, itself extracting the

relevant information for time-frequency representations from signals corresponding to the event.

These three branches configure themselves automatically by statistical learning on the data bases of seismic events.

- *Learning from examples*

Learning from examples consists of building a model of the decision-making system by progressive adjustment of parameters based on data. This model must be able to associate the right decision (output) to a set of data describing the case being processed (inputs). This is carried out progressively, by iterative presentation of cases available in the example base inputting the system. Such a procedure is shown in the flow chart of figure 5.

According to the invention, the learning model can either be a network of artificial neurons or a fuzzy expert system.

Once the system has ended its learning phase, its internal parameters are set and the system is ready for use.

- *Neural network of the "multilayer Perceptron" type*

Such a network of artificial neurons of the "multilayer Perceptron" type is a special model of a neural network able to be used as a decision-making system. It is constituted of a network of robots for simple calculations, "artificial neurons".

A neuron N^j, as shown in figure 6, is an entity constituted of a weight-vector $\mathbf{W}_j=\{w_{ij}\}$ and a non-linear transfer function ϕ. It allows a vector input $\mathbf{X}=\{x_i\}$

and carries out a transformation of these inputs of the type $y_j = \phi\left(\sum_i w_{ij} x_i\right)$.

Similar to the vocabulary used in neurophysiology, one says that each input x_i is linked to the neuron N^J by a synaptic connection. A synaptic weight w_{ij} modulates the efficiency of this connection.

In a network of artificial neurons, as shown in figure 7, the neurons are assembled in successive *layers*. A layer is defined as a set of neurons not having connections between each other, but able to have connections with neurons of the preceding layers (inputs) or following layers (outputs). In general, only neurons of successive layers are connected.

Learning consists of progressively modifying the weights values w_{ij} until the outputs of the network, which is constituted of a certain number of neuron layers, correspond to the required outputs.

In order to achieve this, one defines a classification error one wishes to minimise. The most commonly used error is the mean square error, defined by $E = \sum_{k=1}^{Noutputs} \left(z_k - z_k^{required}\right)^2$. The method consists of making a gradient decrease on the weights by the equation $\Delta w_{ij} = -\alpha \frac{\partial E}{\partial w_{ij}}$ with $\alpha > 0$. This equation, when developed, provides the correction formula for each weight of the network.

- *Fuzzy expert system*

A fuzzy expert system is another system model for decision-making. It has the advantage over a neural

network of giving a form of explanation for its decisions. It is constituted of a set of calculation units, the "fuzzy inference rules".

A fuzzy inference rule is an entity of the form "if <premise> then <conclusion>". The premise is the part sought to put into correspondence with the input data.

In fact, a fuzzy set is a set whose borders are progressive, contrary to a classic set, which has defined borders. Thus an element is more or less part of each fuzzy set. When the data are of dimension 1, a classic set can be represented by a rectangle (membership=1 inside, 0 outside), whereas a fuzzy set can be a triangle, a trapezium a Gaussian form…

In the same way as above, learning consists of modifying progressively the parameter values until the outputs of the fuzzy expert system correspond to the required outputs.

Four types of parameters are calculated by learning: the position and width of the fuzzy sets of premises, the weights of the rules and the degree of activation of each class for each rule.

In the operational utilisation phase, the fuzzy expert system provides, besides the class attributed to a seismic event, the list of rules applicable by descending order of relevance. Some of these rules can be in contradiction with the others, which makes it possible to examine alternative solutions, but it is the aggregation of the result of all the rules which provides the overall result.

Therefore, at the disposal of the user, there exists:

- the initial decision (earthquake, explosion, rock burst);
- the list of applicable rules;
- the list of rules in contradiction to this decision;
- the reason for the decision of each rule (through examination of the coherence between the data and the corresponding fuzzy sets).

An example of decision rule found by the system is given below:

if (Time is the *middle* of the afternoon)
and (Latitude is *very close* to 43.5°N)
and (Longitude is *very close* to 5.5°E)
and (Magnitude is *about* 2.7)
and (Date is *preferably* Saturday)
then (with level of confidence=0.8)
(earthquake is improbable)
(explosion is probable)
(rock burst is improbable).

In the invention, for reasons of difficult convergence, this gradient is parameterised by introducing intermediate variables. If one wishes to carry out a gradient decrease on a parameter p with $p=\phi(s)$, ϕ being a differentiable function, strictly monotonic, independent from p and values of examples serving for learning, one has the same final solutions by carrying out a gradient decrease on s. The advantage of such a change of variable is that it becomes possible to change the way of reaching the solution,

and in particular to facilitate convergence in difficult cases.

In the invention, the following parameters are optimised:

(1) The position y of the fuzzy sets of premises: when the gradient decrease is applied directly on this parameter, one generally obtains difficult convergence. This is explained by the fact that the variation of the position y of the fuzzy sets of premises is not an increasing function of the distance from the example. This phenomenon is corrected by posing $x=y/\sigma$.

(2) The width σ of the fuzzy sets of premises: when the data are structured in sets of very different sizes, the algorithm cannot converge. By studying the relative variation σ/σ, one discovers that it is not bounded (that is to say that nothing prevents it tending towards infinite values). When the data are very grouped, this variation does in actual fact take very high values. In order to have a lower relative modification when the data are close, one poses $s=\ln(2\sigma^2)$.

(3) The weights ρ of the rules: this is the most difficult parameter to set. With a direct gradient decrease, the lowest weights diminish and become negative, which makes them lose all significance and makes the algorithm diverge. Thus one chooses a function for positive activation by imposing a supplementary restriction: for different examples with the same activation level of the rule, the variation of this level must be the same if the conclusions are equal. The consequence is that the relative variation

of the weights of the rules must be constant when the examples have the same degree of belonging to the fuzzy sets. This is carried out by posing $r=\ln(\rho)$.

(4) The degree of activation d of each class for each rule.

The gradient decrease is thus carried out not on y, σ and ρ, but on:

- $x=y/\sigma$
- $s=\ln(2\sigma^2)$
- $r=\ln(\rho)$

For d, one does not carry out any change of variable. These changes in variables ensure very good quality of convergence and allow very efficient fuzzy expert systems to be obtained.

- *Base of examples and validation*

The base of examples used must verify two fundamental principles:

- to be *qualitatively* representative of the real problem (distribution of examples in conformity with the real distribution);

- to be *quantitatively* representative of the problem (number of examples sufficient to constitute a satisfactory sampling).

There are several methodologies for learning and validation. In the simplest procedure, one divides the base of examples into two disjoined bases: the learning base and the test base. One trains the system by learning on the first and one verifies its correct operation on the second. A base of examples that does not conjointly verify the two properties mentioned above runs the risk of leading to a system incapable of

generalising correctly, that is to say of operating on new examples, not presented during the learning stage.

Whether it concerns artificial neuron networks, fuzzy expert systems or more generally any system conceived by statistical learning on experimental data, it is of prime importance to use a base of examples which is adequate in quality and in quantity, and to validate the system produced by rigorous procedures.

Detailed description

• *Description of a seismic event*

A seismic event to be identified can be described by:

- the signals data coming from the network of seismic stations, or

- highest level properties, measurable directly or calculated by geophysical models. For example, one can use the location of the event (latitude and longitude), its magnitude and the moment it occurred (time and day of the week). For example the high level information is as follows: Thursday 7 April 1966 at 12hr, an earthquake of magnitude 1.4 occurred at longitude 02°35'06" East and latitude 49°12'25" North.

• *The neuro-fuzzy classifier*

The neuro-fuzzy classifier (NFC expert), as shown in figure 8, is constituted of a neuro-fuzzy coding of the data followed by a multilayer perceptron. It is applicable to high level data.

Neuro-fuzzy coding consists of associating several coding cells to each input variable (or set of input variables), each cell having a region of influence

modelled by a function defining its activation mechanism. The presentation of a vector of values then generates an activation diagram for the associated coding cells.

Figure 9 shows this mechanism for activating coding cells. Presentation of a value generates an activation diagram corresponding to the impulse response of each activation function to the value presented. The levels of grey attributed to the centres of the cells indicates their activation level comprised between 0 and 1 (black: 1, white: 0).

Figure 10 shows examples of activation diagrams generated by presentation of typical values. It concerns a coding of cursor type. The low values (or high respectively) preferentially activate the left cells (or right respectively).

The interests of this coding are multiple:

- by its very nature, it makes it possible to represent incomplete, imprecise or uncertain data and to use them efficiently for the decision-making;

- by its non-linear processing properties of data, it facilitates later processing (here, the classification).

This neuro-fuzzy coding is carried out in several successive stages: definition of sub-groups of characteristics, choice and placing of coding cells assigned to each group, definition of parameters for the region of influence of each cell. The details of this procedure are explained in document reference [8].

Once the data have been coded, they are analysed by the multilayer perceptron which then calculates the class.

- *The fuzzy expert system*

In an embodiment the system according to the invention comprises a single processing branch based on such a fuzzy expert system.

The fuzzy expert system (FES expert) is also applicable to high level data.

In figure 11, a fuzzy expert system with five rules is shown (one rule per line).

For each line, the five columns on the left represent the premises and correspond to five entries: time, latitude, longitude, magnitude and date. The premises are composed of fuzzy sets in Gaussian form which cover the domains of the input variable leading to reinforcement of the activity of the rule.

Four types of parameters are calculated by learning: the position and the width of the fuzzy sets of premises (columns 1 to 5), the *weights* of the rules (column 6), which makes it possible to specify the degree of importance of each rule in the decision process, and the degree of activation of each class (natural earthquake, explosion or rock burst) for each rule (columns 7 to 9).

Each time an example to be classified is presented, a calculation is made of the contents of column 10 and column 6:

- Column 10 gives the activation of each rule (and thus enables estimation of its fit with the case being processed).

• Line 6 is the synthesis of the decisions from the five rules and gives the overall response of the fuzzy expert system (here, the decision is "explosion"). This synthesis is made by calculating the barycentre of the decisions from all the rules (columns 7 to 9) weighted by the corresponding activation level (column 10). In figure 11, the position of the barycentre for each class is symbolised by a vertical trace line 6, columns 7 to 9.

Learning is carried out in two stages:

- a first phase consists of positioning the fuzzy sets (centres and widths), for example by means of an algorithm called fuzzy C-averages, as described in document reference [9];

- a second phase consists of producing a gradient decrease on the four types of parameters.

• *Neural network with local connections and shared weights*

Contrary to the two preceding branches, the neural network with local connections and shared weights (TDNN expert) allows input of the seismic signals themselves and learns to extract by learning not only the decision procedure, but also the discriminant parameters which will serve as base for this decision. This neural network is of the multilayer perceptron type with local connections and shared weights taking as input the pre-processed spectrograms of seismic signals, as described in document reference [10]. These spectrograms are obtained by applying a sliding window Fourier transform on the signal.

Figures 12A to 12D show the successive pre-processing applied to each seismic signal, resulting in a final spectrogram with 15 frequency bands: figure 12A shows the initial signal; figure 12B shows the spectrogram deduced from the signal with 50 frequency bands; figure 12C shows the "noise-suppressed" spectrogram; figure 12D shows the spectrogram after reduction from 50 to 15 frequency bands.

The spectrogram obtained is then pre-processed and next presented as input for a neural network of the TDNN type. Each network is specialised in the treatment of signals recorded by a given station.

Figure 13 shows the architecture of a TDNN network specialised in classification of spectrograms deduced from signals recorded by a given seismometer, this network comprising four neuron layers. The input layer has local connections and shared weights (4 frames with a delay of 2 frames) with the first hidden layer. The latter also has local connections with shared weights (9 frames with a delay of 5 frames) with the second hidden layer, totally connected to the last layer.

The shared weights make the architecture stronger for small differences in phase recordings or missing or erroneous frames. However, because of the speed of propagation of the P waves (compression) and S waves (shearing), the time between the arrival of phase P and phase S varies in function of the distance between the recording station and the epicentre of the event, which complicates learning. The solution adopted consists of aligning the recording of phase P on the 10th frame and that of phase S on the 60th frame.

- *Final decision making*

For the final decision-making, it is assumed that all the outputs are comprised within the real interval[-1,1]. This decision-making consists of an association of answers provided by the three branches in order to increase reliability. In can be carried out by a calculation of mathematical averages on the homologous outputs of each of the three branches. For each of the three outputs S_i of the overall system one then has:

$$\underset{i=1\ 3}{S_i} = \frac{1}{3}\sum_{j=1}^{3} S_{ij}$$

The certitude of the answer is evaluated by a coefficient calculable only if the system is in a situation for decision-making (that is to say if there is one and a single strictly positive output). This coefficient is then equal to the average of the absolute values of the outputs:

$$K = \frac{1}{3}\sum_{i=1}^{3} |S_i|$$

- $K < 0.2$: doubt
- $K \in]0.2, 0.4]$: caution
- $K \in]0.4, 0.6]$: reasonable certainty
- $K \in]0.6, 0.8]$: high certainty
- $K > 0.8$: almost absolute certainty

Thus, for example, one can obtain:

System	Class chosen	Details of responses per class	Degree of certainty
1	Class 3	(-0.9 –0.4+0.8)	0.7 high certainty
2	Undetermined 1 or 3	(+0.1 –0.5+0.3)	Complete uncertainty
3	Class 1	(+0.2 –0.6-0.2)	0.3: caution
Fusion	Class 3	(-0.2 –0.5+0.3)	0.3: caution

<u>Example of implementation of the invention: discrimination of regional seismic events</u>

• *Localisation of the event*

The discrimination "natural event / artificial event" is a major step in seismic surveillance, carried out rapidly from reading the signals during the reduction stage, and then improved with each new processing. It is estimated that nearly seven years are needed for analysts to become completely operational. Since these analysts are real experts, it is difficult to describe their reasoning method clearly, since it is based both on expert know-how and on case-by-case reasoning.

The location of a seismic event is obtained after a succession of exchanges between two principal stages:

- the recording of the different seismic phases carried out on signals registered by stations detecting the event and the calculation of the magnitude;

- the localisation itself, carried out by a mathematical model created by seismologists.

After the recording stage, the localisation of the event can be carried out using a simulation software known to those skilled in the art. It uses

seismological models containing information about the speed of waves, the different types of waves and their propagation mode, altitude corrections according to stations etc. Several localisation hypotheses are proposed, associated to a degree of data consistency. If they do not satisfy the expert, he modifies his phase recordings and then restarts a localisation search. This cycle is repeated until a result considered to be satisfactory is obtained.

The quality of the localisation depends on the number and quality of the stations used for localising the event, together with their azimuth distribution. In general, events located in France are better localised than events abroad. To improve localisation in the latter case, experts regularly consult data from abroad. With French data alone, the precision of localisation of events in France is on average five kilometres. In the best of cases, it is estimated at about one kilometre.

Table II at the end of the description gives an example of the results provided by the localisation procedure. The upper part resumes the results obtained: for each value of time of origin, of magnitude and localisation (latitude-longitude) an estimated level of inaccuracy is associated. The lower part names the stations taken into account for the localisation and the mean square errors (MSE) obtained as a function of the hypothesis of epicentre depth. In the case of rock bursts, the depth is set arbitrarily at a depth of one kilometre.

- *Characterization of the event*

Here we are concerned by local and regional seismic events, meaning those in mainland France or adjacent regions. These events are often described as *close* as opposed to *distant* teleseisms (epicentre situated at several thousands of kilometres from the sensor).

Three types of seismic events have to be discriminated:

- earthquakes, seismic events of natural origin;
- terrestrial explosions (blasting in mines, quarries, work-sites etc.) or in the sea (bomb disposal, weapons testing etc.);
- rock bursts corresponding to the collapse of a mining layer and associated with the operation of the mine.

Analysis of the state of the art has demonstrated the failure of approaches based on discrimination relying on seismic signals alone. Thus one needs to use all the available data by adopting an approach based on multi-expert and multi-source merging. The concept of the system of automatic discrimination of seismic events is based on three modules:

- the first two (NFC and FES experts) are modules carrying out discrimination from high level data only, deduced by the inverse model of the LDG laboratory. Thus, at this level, no seismic signal is taken into account directly;
- the third (TDNN expert) is based on the analysis of the seismic signals.

- *Data used*

geographic spread of events:

The seismic events to be analysed are spread over the whole of French mainland territory and an adjacent perimeter. The epicentres of the events recorded by the LDG laboratory between 1962 and 1996 are shown in figure 14.

high level data:

Each seismic event is characterised by the following information: the date and time of origin of the event, the latitude and longitude of the epicentre, and its magnitude.

The time and the date are stored because of the rules about quarry or mine blasting in France, forbidding blasting at night or during weekends or public holidays. Nonetheless, permission is given for certain work-sites, for example to avoid disturbing traffic.

The magnitude is recorded since, according to seismologists, rock bursts reach a typical magnitude (about 3). Furthermore, only earthquakes can produce greater magnitudes. Several values of magnitude are taken into account when they are available.

The localisation of the epicentre, characterised by its latitude and its longitude, is also a major characteristic. However, there are certain mines located in regions of high seismicity and capable of provoking rock bursts.

low level data:

Low level data are signals arriving from the 42 seismic stations of the LDG laboratory (see figure 1). The pre-processing relates essentially to the creation of spectrograms of seismic signals, which are non-

stationary. These spectrograms are obtained by application of a sliding window Fourier transform on the signal. To begin with, the signal sampled at 50 Hz, is segmented into two-second frames delayed by one second by a Hamming code window. Next, the spectral energy density is calculated for 50 frequency bands, eliminating the continuous component. Then a logarithmic transformation is applied with noise suppression, with a supposedly logarithmic model, in each band according to the equation $\max(\ln(1+x)-\mu(\mathit{noise})-\sigma(\mathit{noise}),0)$, where $\mu(\mathit{noise})$ and $\sigma(\mathit{noise})$ correspond to the average and the deviation type of the noise estimated over a period anterior to the recording of the wave P. Finally, the number of frequency bands is reduced from 50 to 15 through a pseudo-logarithmic compression of high frequencies.

- *Results obtained*

The system described above classifies French regional seismic events with the following level of performance:

- 86% for earthquakes;
- 91% for explosions;
- greater than 99% for rock bursts.

The overall level of performance is about 90%.

TABLE I

CLOSE BULLETIN: 09 SEP 1998 TO 15 SEP 1998 P 1998-037

CLOSE EARTHQUAKES-SUMMARY-No.EVENTS: 34

TIME OR: time of origin (TU)
LAT: latitude of epicentre (deg)
LON: longitude of epicentre (deg)
DEP: depth of epicentre (km)
LM: local magnitude
MSE: mean square error (s)

DATE	TIME OR.	LAT	LON	DEP	LM	MSE	REGION
09 Sep	4 19 55.8	44.15 N	11.59 E	2	2.9	.8	44 km SE Bologna
09 Sep	11 27 59.3	39.73 N	16.28 E	2	5.0	1.4	162 km S Bari
09 Sep	11 33 35.6	44.43 N	9.83 E	2	3.0	.7	71 km E Genes
09 Sep (PGT = 20H 50min)							
10 Sep	7 19 30.1	45.63 N	11.18 E	2	2.7	1.1	49 km E Trente
10 Sep	15 41 48.2	40.67 N	.16 W	5	3.0	1.3	57 km W Vinaroz
10 Sep	18 13 40.7	43.07 N	.40 W	2	2.1	.3	22 km SE Oloron-Ste-Marie (64)
10 Sep	20 41 27.1	45.42 N	6.66 E	2	2.2	.7	29 km NE Saint-Jean-de-Maurienne (73)
11 Sep	8 51 55.4	42.03 N	9.53 E	2	2.5	.3	44 km SE Corte
11 Sep	11 23 48.9	44.69 N	7.18 E	2	2.2	.3	44 km NW Cuneo
12 Sep	4 28 48.2	42.92 N	.20 E	5	1.8	.2	17 km S Bagneres-de-Bigorre (65)
12 Sep	5 30 20.9	45.40 N	6.67 E	2	1.7	.2	29 km NE Saint-Jean-de-Maurienne (73)
12 Sep	8 47 31.6	44.61 N	10.22 E	2	2.7	.6	30 km W Bologna
12 Sep	9 40 56.6	41 27 N	1.40 E	2	2.5	1	66 km W Barcelone
12 Sep	9 48 8.1	44.06 N	12.72 E	2	3.1	.6	78 km NW Ancone
12 Sep	13 56 44.3	47.94 N	2.55 W	2	1.8	.5	34 km SE Pontivy (56)
12 Sep	22 13 10.3	51.47 N	6.88 E	2	2.8	.3	29 km N Dusseldorf
13 Sep	2 9 31.5	46.12 N	7.94 E	2	2.4	.6	36 km SE Sierre
13 Sep	4 23 28.3	39.64 N	.75 W	2	2.8	.6	35 km NW Valence
13 Sep	15 41 37.2	43.05 N	.48 W	2		.1	19 km SE Oloron-Ste-Marie (64)
14 Sep	3 33 33.0	44.28 N	10.93 E	2	3.4	.7	41 km SW Bologne
14 Sep	5 24 49.7	38.20 N	13.03 E	2	4.0	1.5	32 km N Palerme
14 Sep	6 57 37.4	44.37 N	10.62 E	2	2.7	1.0	59 km W Bologne
14 Sep	9 7 36.6	48.10 N	7.94 E	14	3.8	.3	13 km NE Freiburg-im-Briagau
14 Sep	10 21 11.6	44.26 N	10.89 E	2	3.2	.5	44 km SW Bologne
14 Sep	13 57 14.0	48.05 N	3.54 W	22		.1	36 km N Lorient (56)
14 Sep (PGT = 17H 5min)							
14 Sep	17 11 2.1	46.18 N	6.79 E	2	2.0	.4	32 km SE Thonon-les-Bains (74)
14 Sep	18 35 8.1	43.65 N	12.42 E	2	2.8	.4	59 km N Perouga
14 Sep	22 39 44.4	44.68 N	7.60 E	2	2.1	.7	31 km N Cuneo
15 Sep	6 24 25.7	43.59 N	7.69 E	19	2.5	.3	24 km S San Remo
15 Sep	15 48 1.8	43.47 N	.65 W	2	2.7	4	30 km NW Pau (64)
15 Sep (ETGT = 18H 5min)							
15 Sep	23 3 52.8	44.22 N	10.77 E	2	2.7	.5	54 km SW Bologne

TABLE II

100596 probul.dat /data/sismic/exploit/dat/P19190.131.tou37:06 MEYDST 1

Number of stations used 11 - Res in bulletin : yes

preloc. lat: 43.2 lon: 5.4 hr: 19 19 53.1

region: 11 km S Aix-en-Provence (13)
rock burst

Time of origin: 19 19 53.8 +/- .3
latitude: 43.43 +/- 1.7
longitude: 5.43 +/- 2.5
Depth: 1. km set

magnitudes:
ampl. 2.8 +/-9.9 sur 1 station
Duration: 2.7 +/- .0 sur 2 stations

rms: .289 nb d'iter: 3

Ellipse: 95% confidence

1/2 long axis: 7.0 km.
1/2 short axis 4.6 km.
azimuth long axis 169.5 degrees

pro	1. km	2. km	15. km	25. km	30. km
lat	43.43	43.44	43.50	43.53	43.36
lon	5.43	5.44	5.51	5.59	5.34
rms	.29	.32	.98	1.65	1.90
nit	3	3	5	8	8

code	ph	< Time >	dist	azi	ampl	per	dur	res	ml	md	res	res	res	res
LRG	pg	19 20 6.5	75	87				-.1			-.1	-.9	-1.7	-1.9
FRF	pg	19 20 10.4	99	81			50.	-.2		2.7	-.2	-.8	-1.3	-1.0
FRF	sg	19 20 21.8	99	81				-.4			-.4	-.3	-.3	-1.5
LMR	pg	19 20 8.7	87	96			50.	.0		2.7	-.1	-1.0	-1.8	-1.1
LMR	sg	19 20 18.8	87	96				-.2			-.3	-.8	-1.2	-1.7
SBF	pg	19 20 21.8	168	72	22.4	.4		-.3	2.8		-.3	-.7	-1.0	1.8
SBF	pn	19 20 20.8	168	72				.5			.6	1.4	2.1	.9
SBF	sg	19 20 41.9	168	72				.3			.3	.8	1.1	3.5
PGF	pn	19 20 37.1	307	107				-.2			-.2	.1	.6	.7
PGF	sn	19 21 9.8	307	107				.4			.5	2.0	3.7	2.6
LRG	sg	19 20 15.8	75	87				.3			.3	.1	-.3	-2.3

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Amended claims to file when entering the National Phase

CLAIMS

1. System of artificial intelligence for classification of events, objects or situations from signals and from discriminant parameters produced by models, comprising at least one processing branch comprising a fuzzy expert system taking a decision according to high level properties and discriminant parameters of lower level extracted from signals by signal processing type procedures, and capable of explaining its decision to the user through the intermediary of rules selected by order of applicability.

2. System according to claim 1 in which, in the fuzzy expert system a gradient decrease is carried out on the parameters:

- $x = y/\sigma$
- $s = \ln/2\sigma^2)$
- $r = \ln\ (\rho)$
- d

with:

- y: position of fuzzy sets of premises
- σ: width of fuzzy sets of premises
- ρ: weights of rules
- d: degree of activation of each class for each rule.

3. System according to claim 1, which is a multi-expert system constituted of at least two independent

processing branches, organising themselves automatically through statistical learning on data bases, having particular properties and merged by a high level decisional system.

4. System according to claim 3, in which one branch comprises a neuro-fuzzy classifier taking its decisions based on high level properties and lower level discriminant parameters extracted from signals by signal processing type procedures.

5. System according to claim 3, in which one branch comprises a neural network with local connections and shared weights constituted of banks of non-linear adaptable filters, itself extracting discriminant information for time-frequency representation of the corresponding signals.

6. System according to claim 1, which is a system for classification of geophysical events.

7. System according to claim 6, in which the high level properties are the localisation, the magnitude, the time and the date.

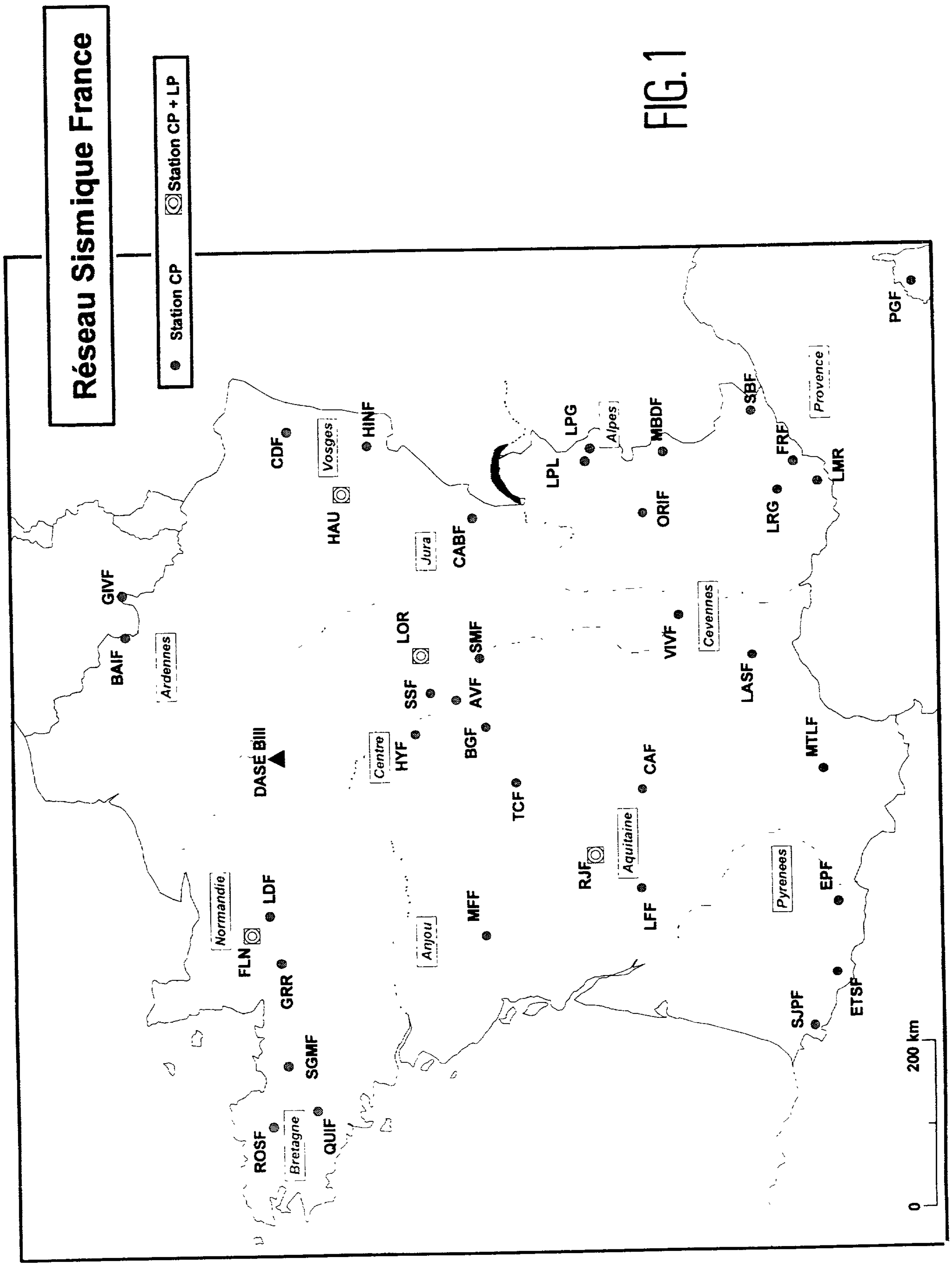

Réseau Sismique France
Station CP
Station CP + LP
GIVF
BAIF
Ardennes
CDF
Vosges
HINF
HAU
Jura
CABF
LOR
SMF
SSF
AVF
BGF
HYF
Centre
DASE BIII
TCF
Normandie
LDF
FLN
GRR
SGMF
ROSF
Bretagne
QUIF
Anjou
MFF
RJF
Aquitaine
LFF
CAF
LPL
LPG
Alpes
MBDF
ORIF
VIVF
Cevennes
LASF
MTLF
SBF
Provence
FRF
LMR
LRG
PGF
Pyrenees
EPF
ETSF
SJPF
0
200 km

FIG. 1

FIG. 2

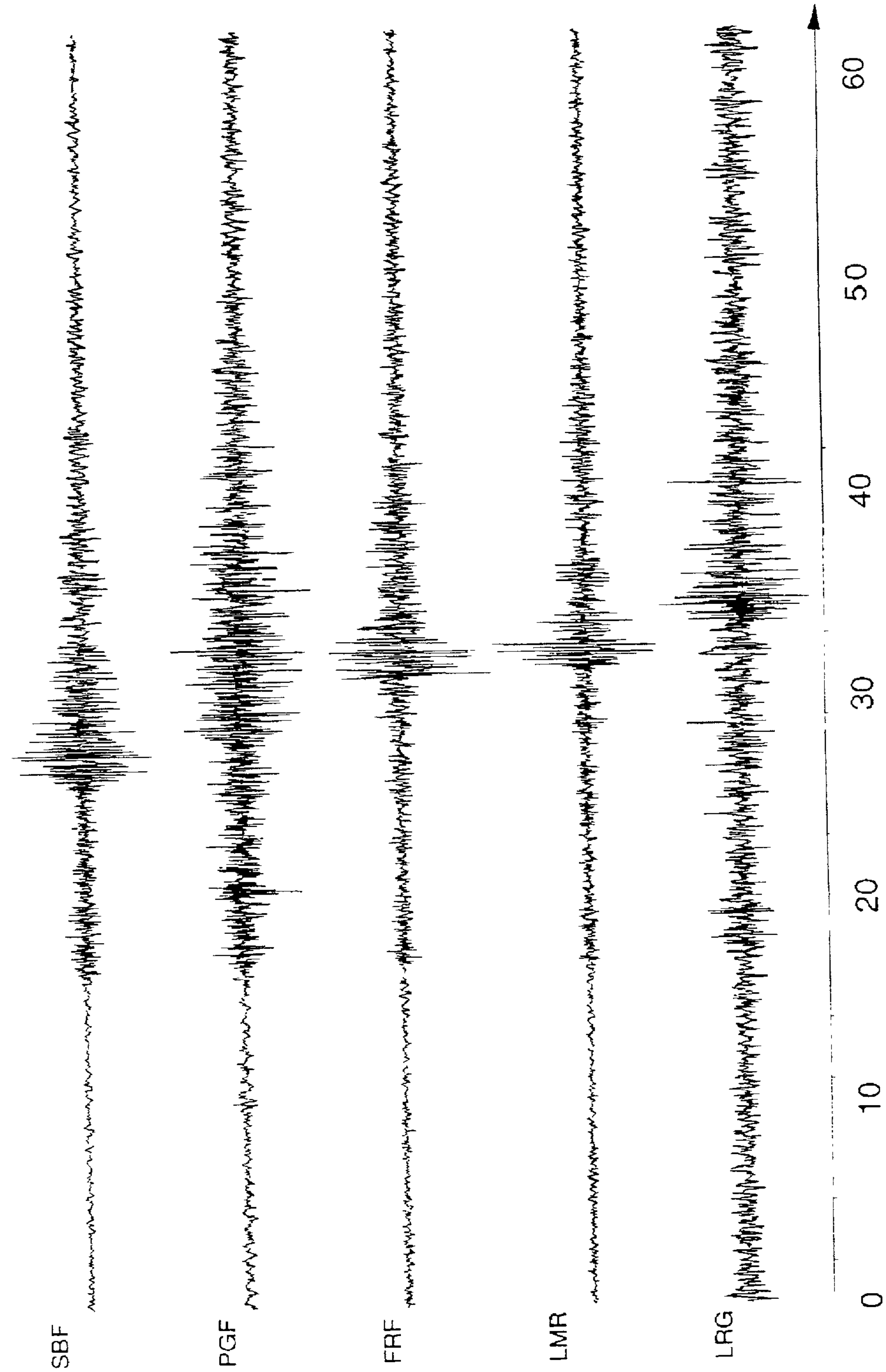
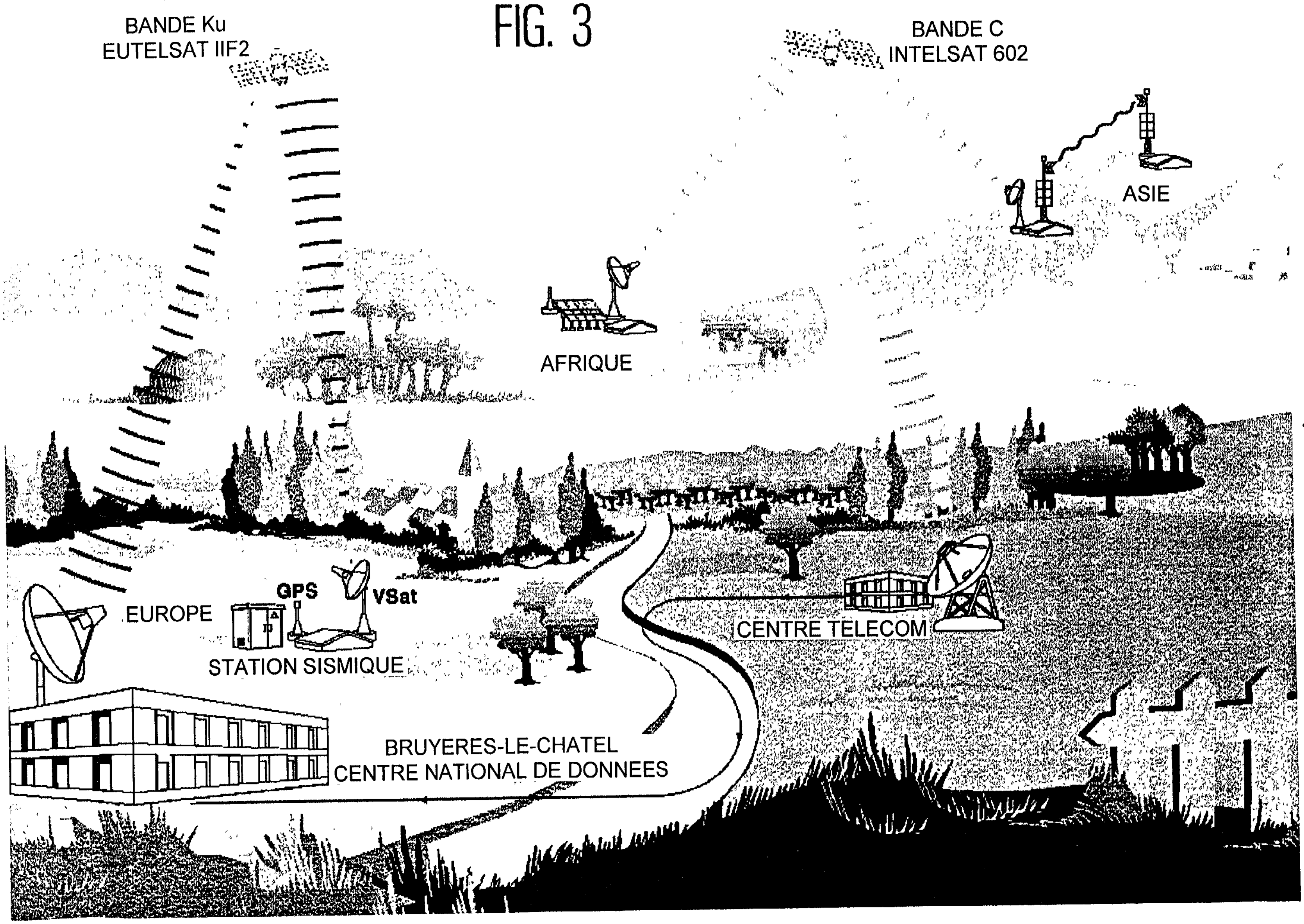


FIG. 3


BANDE Ku
EUTELSAT IIF2
BANDE C
INTELSAT 602
AFRIQUE
ASIE
EUROPE
GPS
VSat
STATION SISMIQUE
CENTRE TELECOM
BRUYERES-LE-CHATEL
CENTRE NATIONAL DE DONNEES

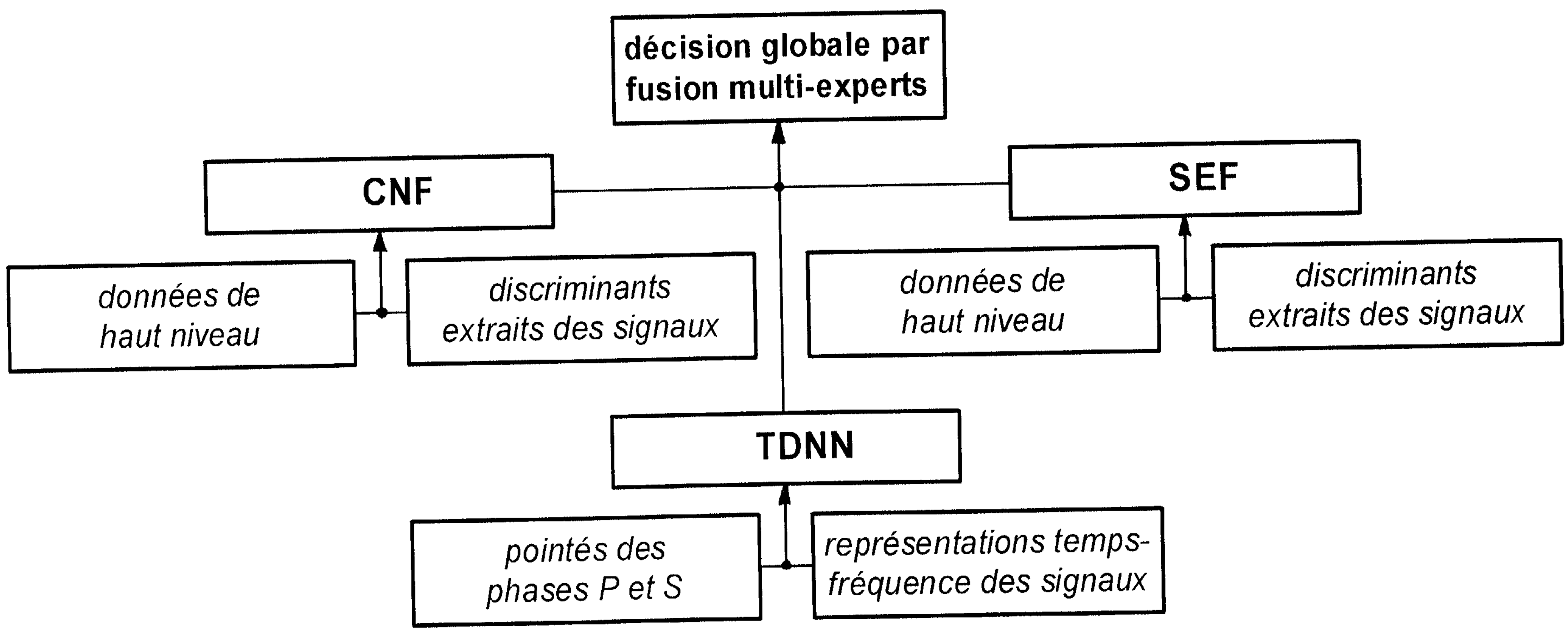
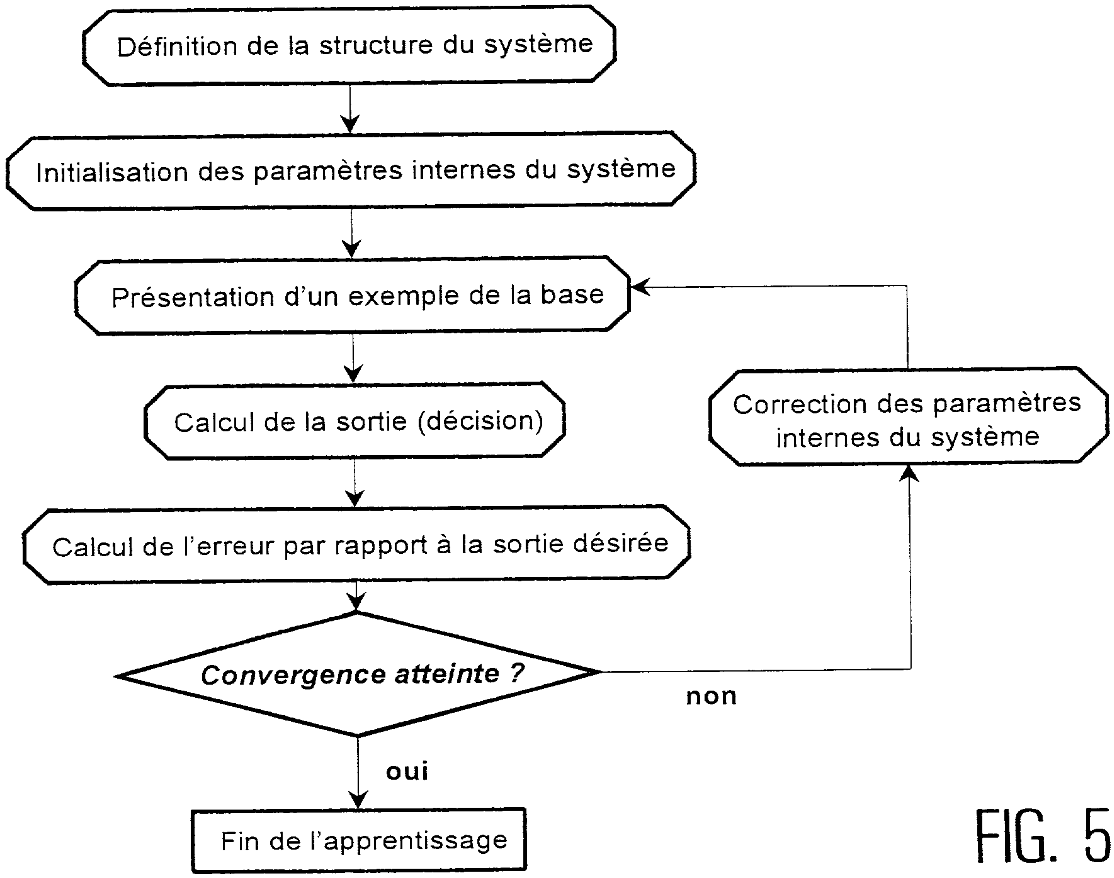

décision globale par
fusion multi-experts
CNF
SEF
données de
haut niveau
discriminants
extraits des signaux
données de
haut niveau
discriminants
extraits des signaux
TDNN
pointés des
phases P et S
représentations temps-
fréquence des signaux

FIG. 4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Initialisation des paramètres internes du système
Présentation d'un exemple de la base
Calcul de la sortie (décision)
Calcul de l'erreur par rapport à la sortie désirée
Convergence atteinte ?
non
Correction des paramètres internes du système
oui
Fin de l'apprentissage

FIG. 5

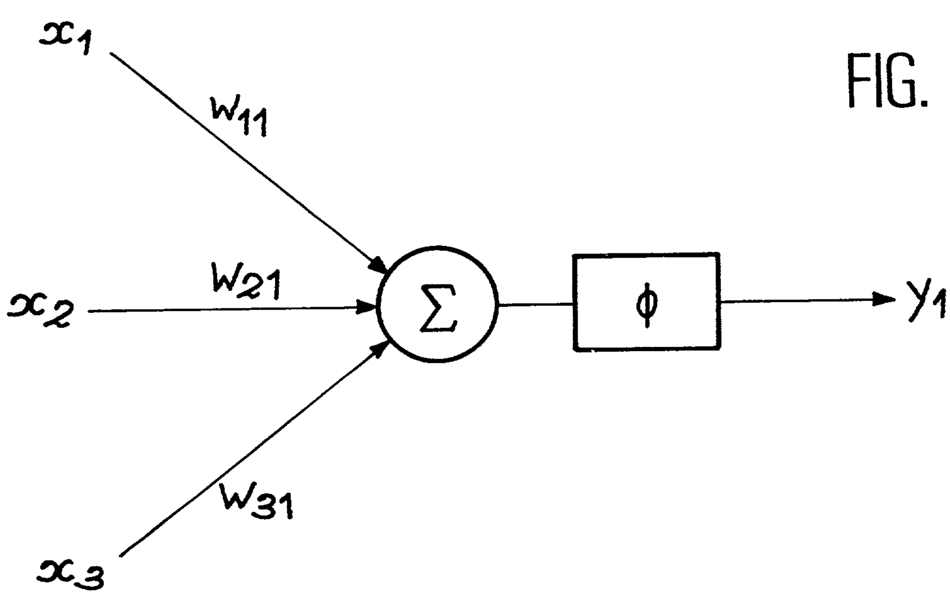
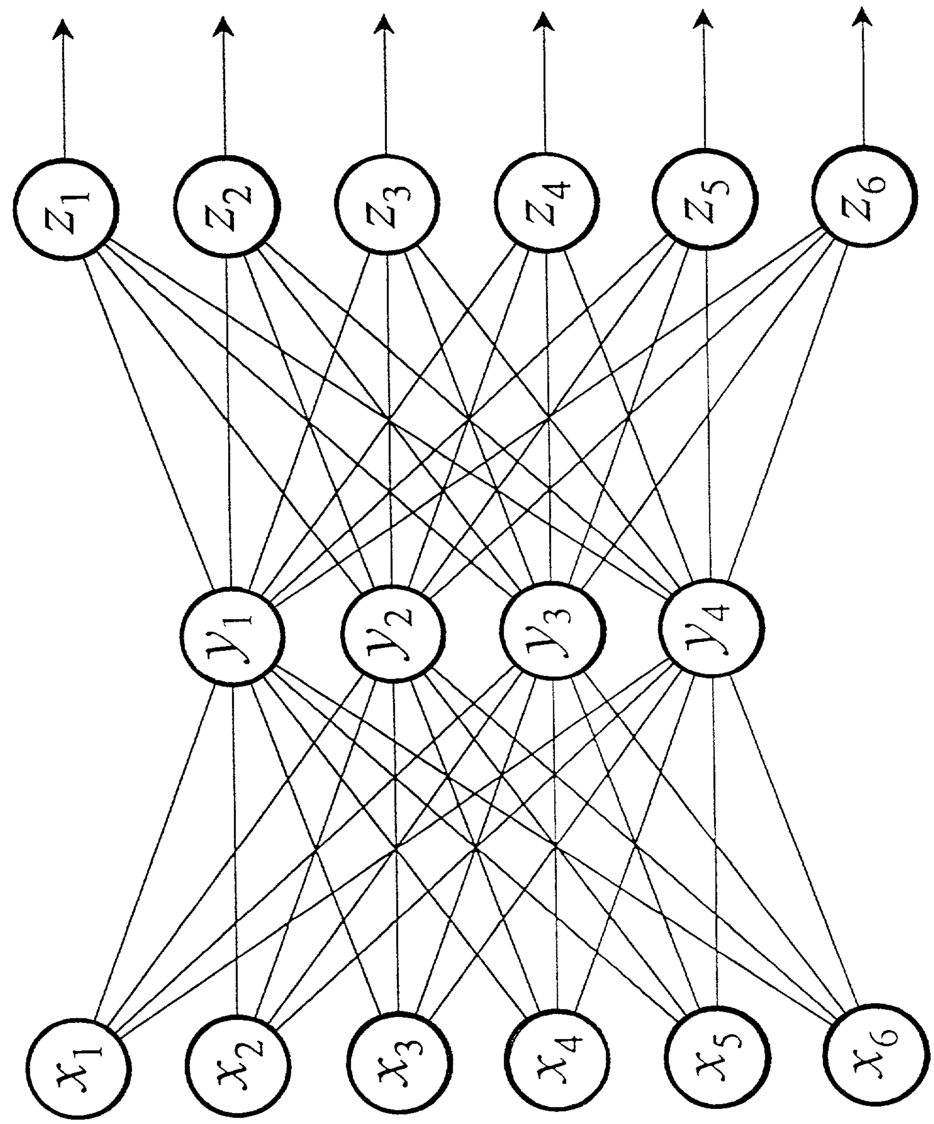
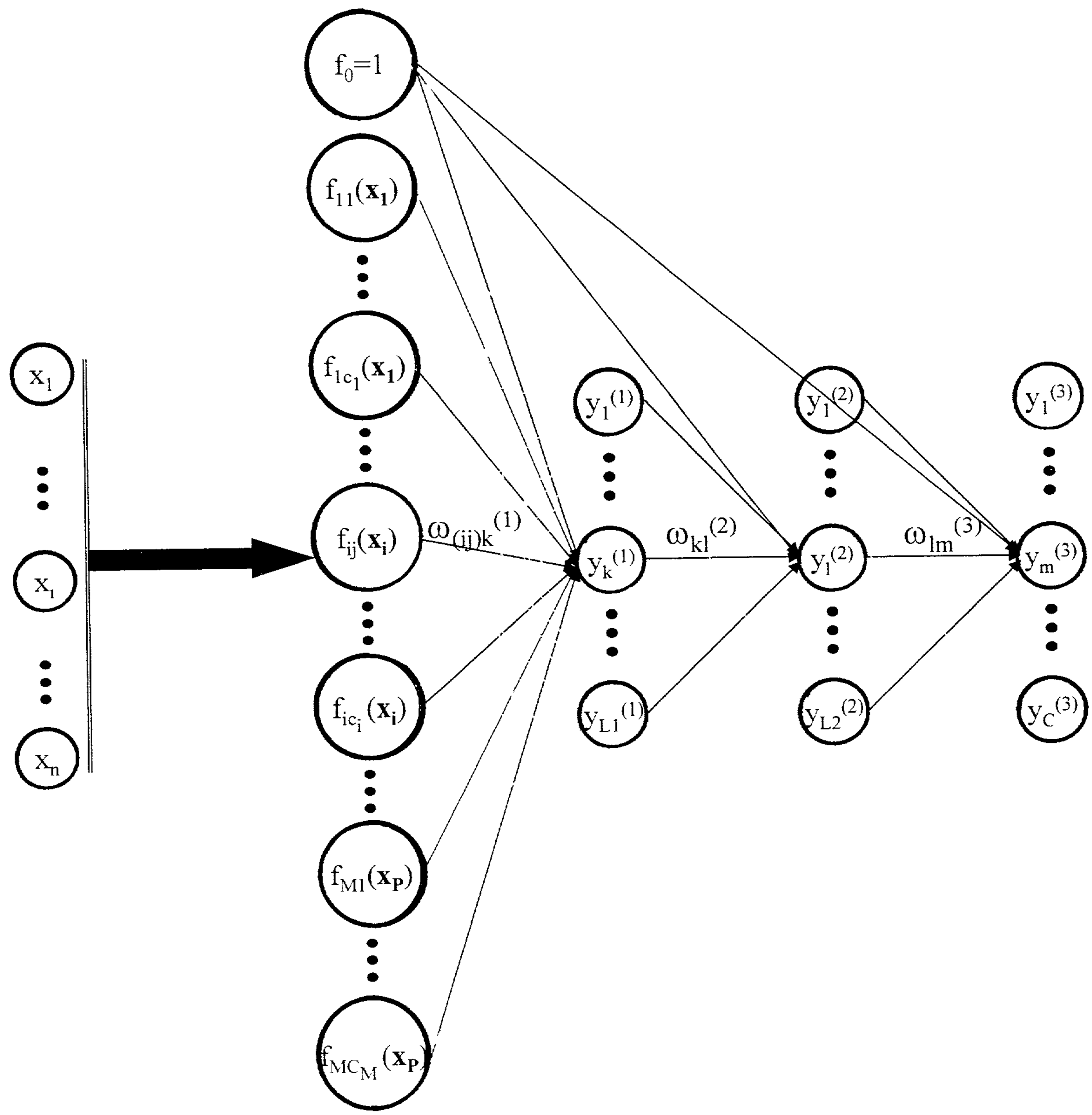

x1
x2
x3
W11
W21
W31
Σ
ϕ
y1

FIG. 6

FIG. 7





$f_0=1$
$f_{11}(\mathbf{x_1})$
$f_{1c_1}(\mathbf{x_1})$
$f_{ij}(\mathbf{x_i})$
$f_{ic_i}(\mathbf{x_i})$
$f_{M1}(\mathbf{x_P})$
$f_{MC_M}(\mathbf{x_P})$
x_1
x_i
x_n
$\omega_{(ij)k}^{(1)}$
$\omega_{kl}^{(2)}$
$\omega_{lm}^{(3)}$
$y_1^{(1)}$
$y_k^{(1)}$
$y_{L1}^{(1)}$
$y_1^{(2)}$
$y_l^{(2)}$
$y_{L2}^{(2)}$
$y_1^{(3)}$
$y_m^{(3)}$
$y_C^{(3)}$

FIG. 8

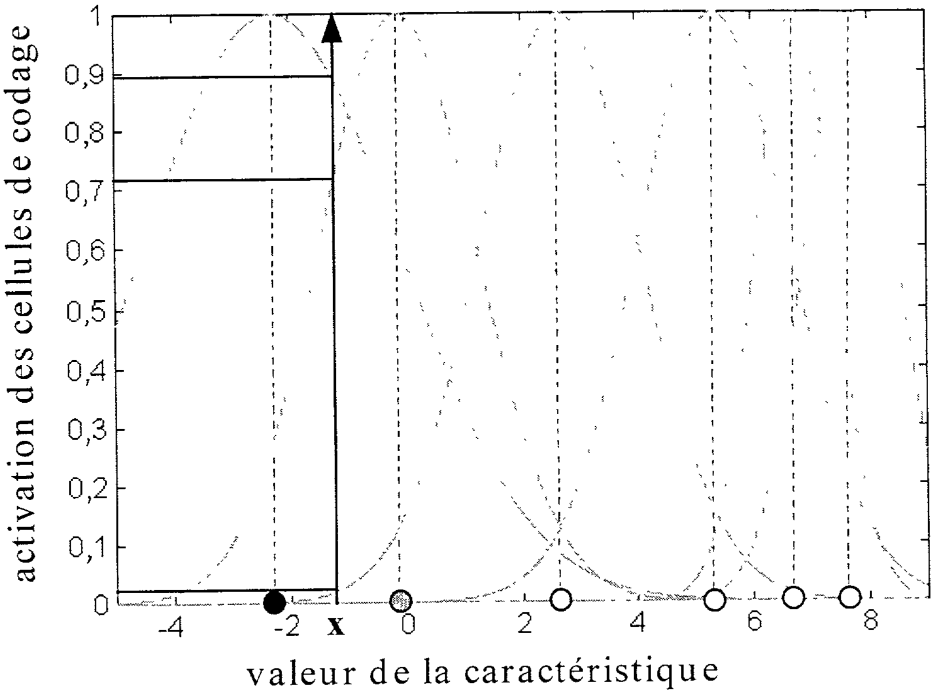

activation des cellules de codage
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
-4
-2
x
0
2
4
6
8
valeur de la caractéristique

FIG. 9

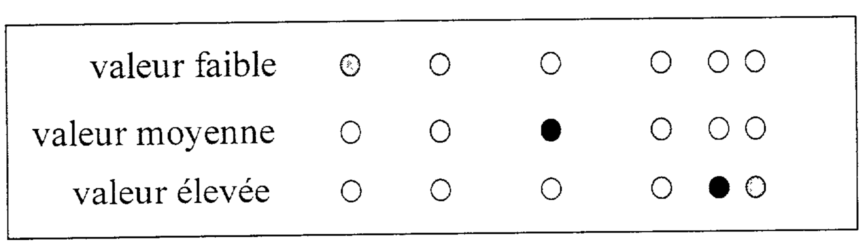

valeur faible
valeur moyenne
valeur élevée

FIG. 10

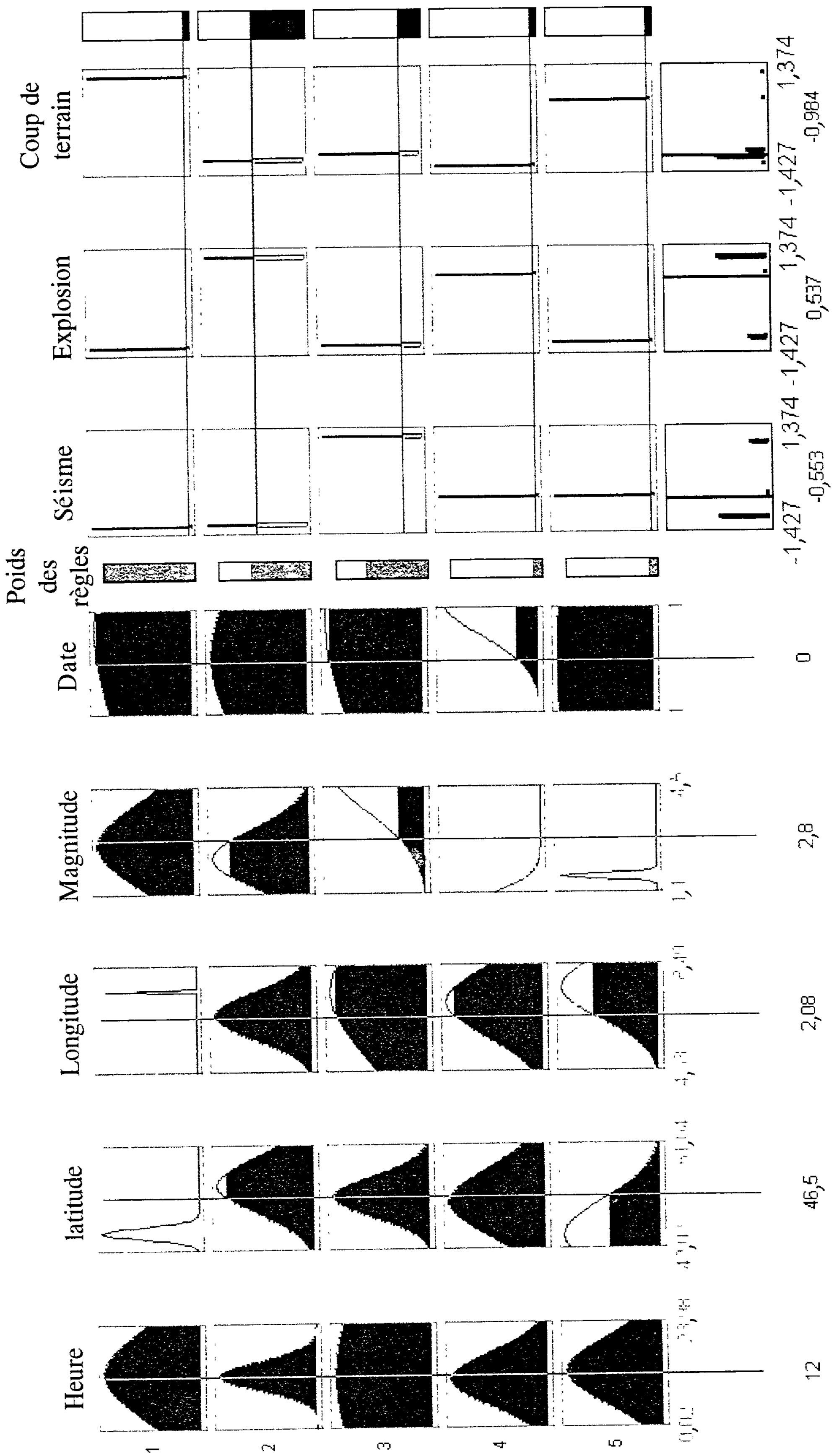

Heure
latitude
Longitude
Magnitude
Date
Poids des règles
Séisme
Explosion
Coup de terrain
1
2
3
4
5
12
46,5
2,08
2,8
0
-1,427
-0,553
1,374
-1,427
0,537
1,374
-1,427
-0,984
1,374

FIG.11

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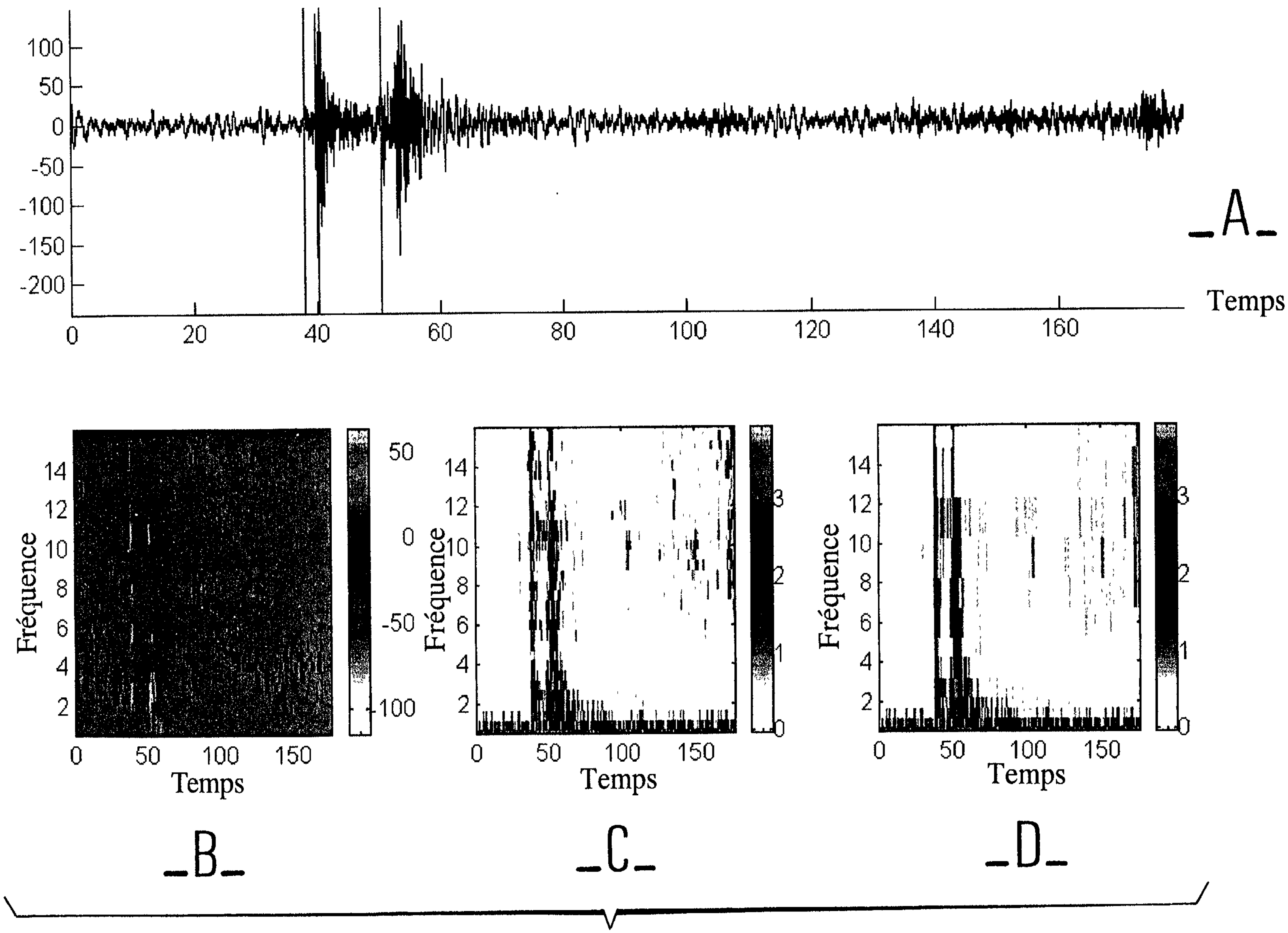


FIG. 12

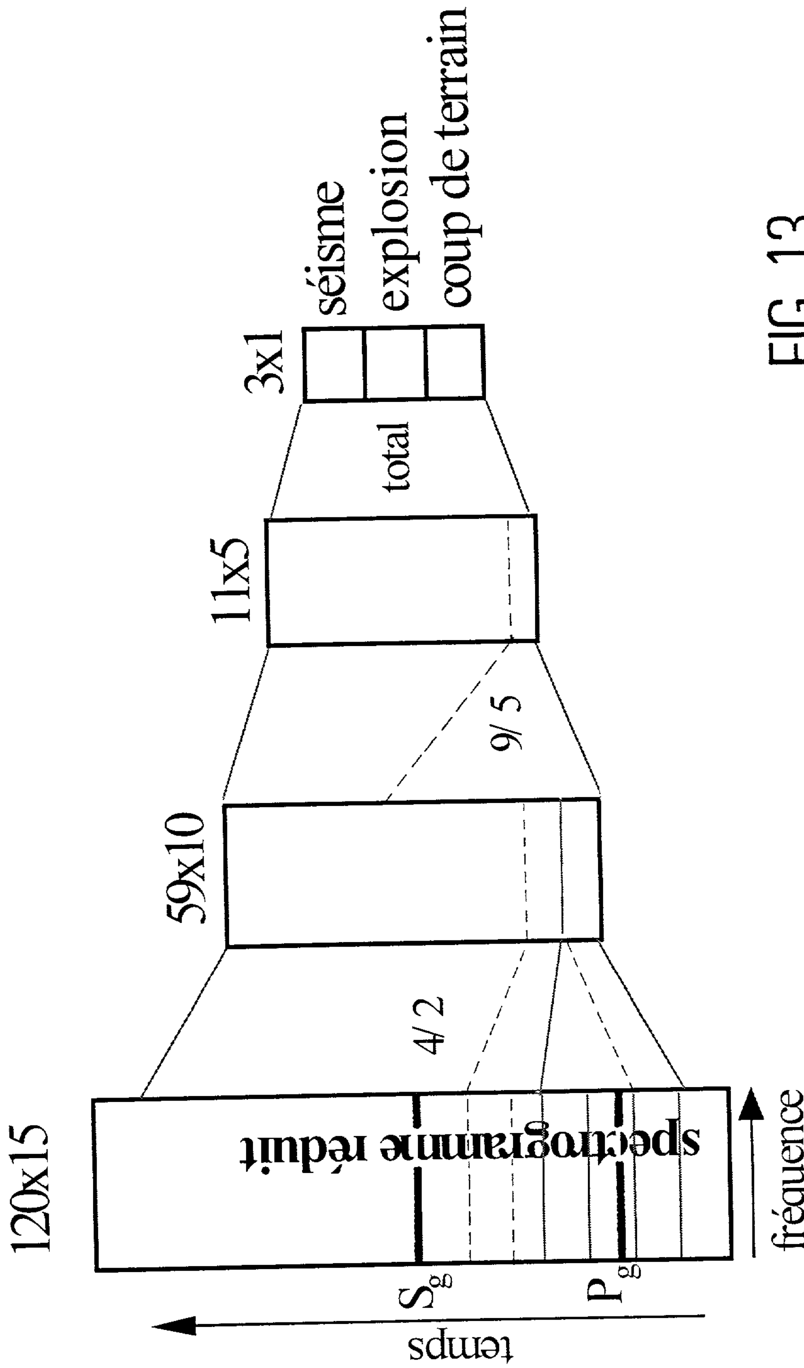
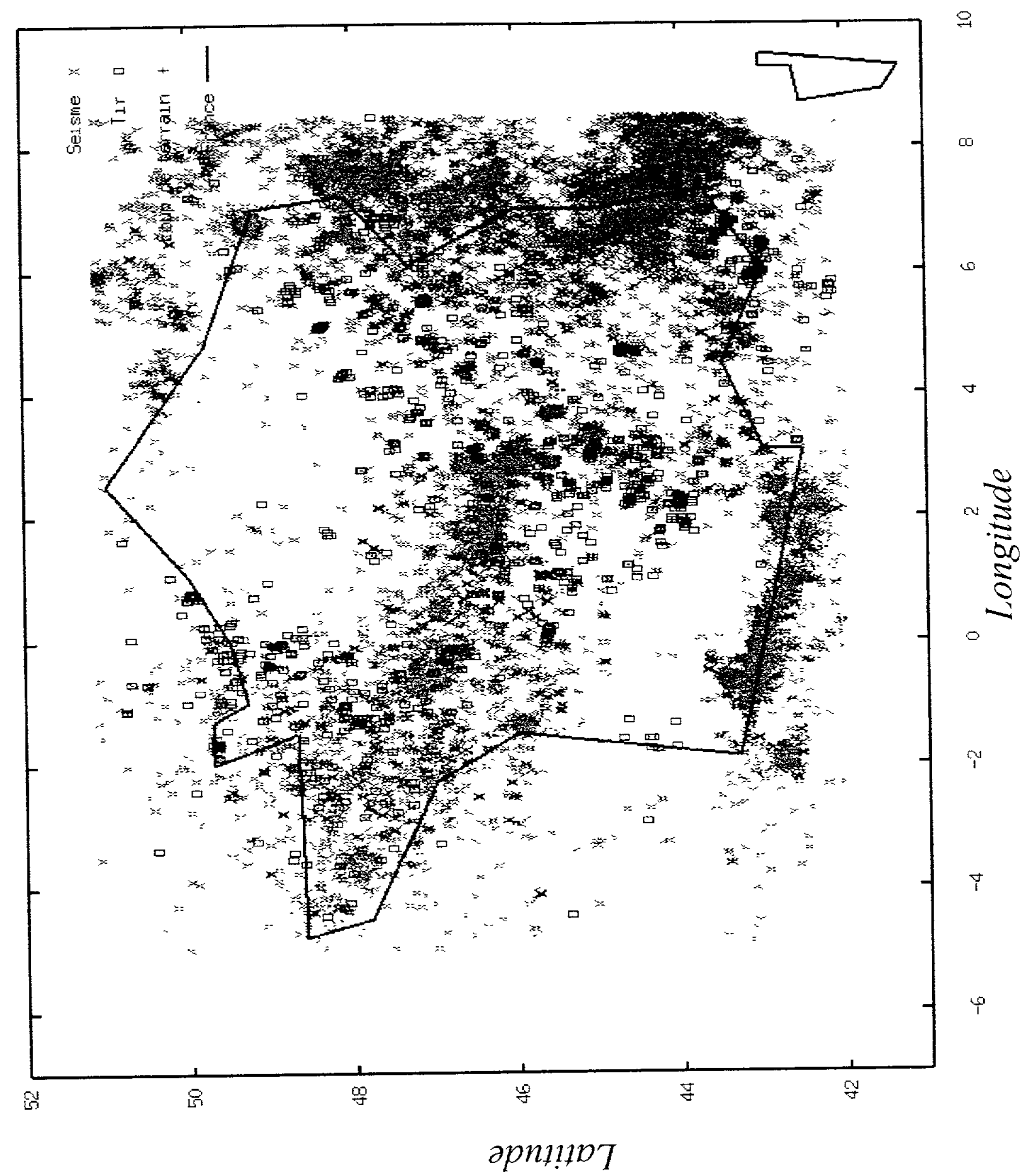

120x15
59x10
11x5
3x1
séisme
explosion
coup de terrain
total
9/ 5
4/ 2
spectrogramme réduit
S_g
P_g
temps
fréquence

FIG. 13

10/009335

FIG. 14



B 13340.3 DB

Declaration, Power Of Attorney and Petition

WE (I) the undersigned inventor(s), hereby declare(s) that :

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

SYSTEM OF ARTIFICIAL INTELLIGENCE FOR THE CLASSIFICATION OF EVENTS, SUBJECTS OR SITUATIONS FROM SIGNALS AND DISCRIMINANT PARAMETERS PRODUCED BY MODELS

the specification of which

☐ is attached hereto.

☐ was filed on

as Application Serial No.

and amended on

☒ was filed as PCT international application

Number PCT/FR00/01804

on June 28, 2000

and was amended under PCT Article 19

on May 11, 2001

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365 (b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application (s)

Application No.	Country	Day/month/Year	Priority Claimed
99 08472	FRANCE	01 JULY 1999	☒ YES ☐ NO
			☐ YES ☐ NO
			☐ YES ☐ NO
			☐ YES ☐ NO

We (I) hereby claim the benefit under Title 35, United States Code, § 119 (e) of any United States provisional application(s) listed below.

(Application Number) (Filing Date)

(Application Number) (Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of prior application and the national or PCT International filing date of this application.

Application Serial No.	Filing Date	Status (pending, patented, abandoned)

And we (I) hereby appoint :William L. Mathis, Registration Number 17,337; Alan E. Kopecki, Registration Number 25,813; Eric H. Weisblatt, Registration Number 30,505; Peter H. Smolka, Registration Number 15,913; Regis E. Slutter, Registration Number 26,999; James W. Peterson, Registration Number 26,057; Robert S.Swecker, Registration Number 19,885, Samuel C. Miller III, Registration Number 27,360; Terase Stanek REA, Registration Number 30,427; Platon N. Mandros, Registration Number 22,124; Ralph L. Freeland Jr., Registration Number 16,110; Robert E. Krebs, Registration Number 25,885; Benton S. Duffett jr., Registration Number 22,030; Robert M. Schulman, Registration Number 31,196; Joel M. Freed, Registration Number 25,101; James A. Labarre, Registration Number 28,632; William C. Rowland, Registration Number 30,888; Norman H. Stepno, Registration Number 22,716; E. Joseph Gess, Registration Number 28,510; Richard H. Kjeldgaard, Registration Number 30,186; Ronald L. Grudziecki, Registration Number 24,970; David D. Reynolds, Registration Number 29,273; T. Gene Dillahunty, Registration Number 25,423; Frederick G. Michaud Jr, Registration Number 26,003; R. Danny Huntington, Registration Number 27,903 and Anthony W. Shaw, Registration Number 30,104; our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of BURNS, DOANE, SWECKER & MATHIS, whose post Office Address is : George Mason Building, Washington and Prince Streets, P.O. Box 1404 Alexandria, Virginia 22313-1404.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true ; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the application or any patent issuing thereon.

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Signature of Inventor

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Signature of Inventor

Date

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NAME OF FOURTH INVENTOR

Signature of Inventor

Date

Residence :

Citizen of :

Post Office Address : The same as residence

NAME OF FIFTH INVENTOR

Signature of Inventor

Date

Residence :

Citizen of :

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